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COMPARISON OF AIR SHOWER AND VEST AUXILIARY COOLING DURING SIMULATED TANK OPERATIONS IN THE HEAT

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

APRIL 1983

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An evaluation of the effectiveness of air shower and vest auxiliary cooling was carried out on two tank crews in combat vehicle crewmen clothing and chemical protective clothing. The M1E1 Main Battle Tank was parked in a climatic chamber with environmental conditions of 91°F dry bulb, and 78°F wet bulb temperature. Crewmen performed standard tank exercises in a closed hatched tank for a duration of 2-hours and 45 minutes. Heart rate, rectal and skin temperatures were monitored continuously on each crewmen. Final rectal, mean body and skin temperatures were statistically higher ($p<0.05$) during air

shower (99.7, 98.6 and 96.3°F, respectively) compared to vest auxiliary cooling (99.0, 95.2 and 87.6°F, respectively). Final heart rate responses were higher ($p<0.05$) during air shower compared to vest cooling (112 and 91 beats per minute, respectively) for the crews. Total sweat losses were also greater ($p<0.01$) during air shower (1.29 liters) compared to vest test (0.64 liters). One crew attempted the exposure with usage of the M13A1 particulate filter in operation. This exposure was discontinued following the incapacitation of two crewmen within 84 minutes, though thermal strain was only moderate. It is clear that vest auxiliary cooling is more effective for crewmen cooling than an air shower. It must also be emphasized that in these ambient conditions, an air shower provides adequate cooling power.

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Abstract

An evaluation of the effectiveness of air shower and vest auxiliary cooling was carried out on two tank crews dressed in combat vehicle crewman clothing and chemical protective clothing. The M1E1 Main Battle Tank was parked in a climatic chamber with environmental conditions of 91°F dry bulb, and 78°F wet bulb temperature. Crewmen performed standard tank exercises in a closed hatched tank for a duration of 2-hours and 45 minutes. Heart rate, rectal and skin temperatures were monitored continuously on each crewman. Final rectal, mean body and skin temperatures were statistically higher ($p < 0.05$) during air shower (99.7, 98.6 and 96.3°F, respectively) compared to vest auxiliary cooling (99.0, 95.2 and 87.6°F, respectively). Final heart rate responses were higher ($p < 0.05$) during air shower compared to vest cooling (112 and 91 beats per minute, respectively) for the crews. Total sweat losses were also greater ($p < 0.01$) during air shower (1.29 liters) compared to vest test (0.64 liters). One crew attempted the exposure with usage of the M13A1 particulate filter in operation. This exposure was discontinued following the incapacitation of two crewmen within 84 minutes, though thermal strain was only moderate. It is clear that vest auxiliary cooling is more effective for crewmen cooling than an air shower. It must also be emphasized that in these ambient conditions, an air shower provides adequate cooling power.

INTRODUCTION

The thermal stress of individuals exposed to hot environments while inside closed crew compartments has been an area of concern for several years. Earlier work by Joy (4) indicated that pilots were exposed to high compartment temperatures while flying missions. Breckenridge and Levell (1) clearly documented that, despite 80°F ambient air temperatures with cloud cover, cockpit air temperatures reached 134°F. These earlier studies pointed out the need for further evaluations of thermal stress on other types of vehicles that were closed and exposed to high ambient temperatures. Goldman and Winsmann (3) examined the thermal stress on crewmen in the Mechanized Infantry Combat Vehicle parked in the desert. As anticipated, the thermal stress was not as severe as the "hot house" effect seen in the AH-1G Cobra helicopter. In fact, internal air temperatures were only slightly higher than ambient. Crewmen had no difficulty completing three hours inside the vehicle.

With the recent concern that the modern battlefield may be contaminated with chemical agents, the issue of thermal stress of crewmen in closed combat vehicles has once again been raised. In addition to the combined thermal stress of hot environments and closed compartments, the requirement of chemical protection has added to the thermal burden on the crewmen. In 1980, crewmen dressed in chemical protective clothing performed routine exercises during simulated tank operations in the desert (7). It was clearly demonstrated that tank crewmen could not tolerate prolonged exposures in a closed-unventilated compartment with the Wet Bulb Globe Temperature (WBGT) index near 95°F. It was also shown that auxiliary cooling provided to the crewman in the form of a vest circulated with cooled liquid substantially reduced the heat stress. Crewmen performed without difficulty with auxiliary cooling, but large decrements in performance without cooling were noted. This study demonstrated a need for auxiliary cooling of crew compartments when operations are planned in a hot and/or contaminated environment.

The Commanding General of the US Army Training and Doctrine Command directed that an evaluation of the effectiveness of air shower and vest auxiliary cooling be carried out. The US Army Research Institute of Environmental Medicine was tasked to monitor the physiological responses of qualified tank crewmen dressed in full chemical protective clothing as they perform tasks in the M1E1 Tank.

METHODS

Subjects

Two 4-men tank crews from the 2nd Battalion, 6th Cavalry, Ft. Knox, KY, were tasked to participate in the evaluation program. These tank crews were qualified by virtue of their meeting standards set forth in the Tank Table 8 qualification tests. The physical characteristics of the crews are outlined in Table 1.

TABLE 1

Physical Characteristics of the Crews

		Height (cm)	Weight (kg)	Age (years)	Body Fat (%)
Crew A	$\bar{X}$	176.3	69.1	26.0	18.8
	SD	5.7	13.4	7.0	4.8
Crew B	$\bar{X}$	177.8	71.0	23.3	13.1
	SD	10.4	8.7	3.3	2.8
Diff	(B-A)	1.5	1.9	-2.7	-5.7
P		ns	ns	ns	ns

M1E1 Main Battle Tank

The M1E1 Tank was parked in a climatically controlled chamber at Aberdeen Proving Grounds (APG), MD, and was modified for testing purposes. The 120 mm gun tube was replaced with a shortened tube to enable turning of the turret in the chamber. The rounds for the main gun were the inert kinetic energy (43.5 pounds, 35 inch) and the inert high explosive antitank (51.7 pounds, 38.5 inch) rounds normally carried in the M1E1. All tank systems were operating except the turbine engine.

Experimental Protocol

Clothing Ensemble. Crewmen were dressed in their standard Combat Vehicle Crewman (CVC) uniforms with Kevlar vests. In addition, chemical protective clothing in MOPP III and IV configurations was worn. MOPP III included overgarment, gloves and boots without mask and hood, whereas MOPP IV included the mask and hood. The heat transfer capability of the clothing in MOPP IV is similar to that of the Army's Cold Wet Uniform when both are worn in a warm environment. The CVC uniform plus full chemical protective clothing have an insulation of 2.64 clo and a permeability index (i_m) of 0.26; the Cold Wet Uniform's clo and i_m are 3.00 and 0.35, respectively. When air temperature is near skin temperature (as in this study), the difference in clo values (2.64 vs 3.00) is relatively unimportant since the actual rate of dry heat transfer in either ensemble will be quite low. The potential for cooling by evaporation of sweat, which is given by the i_m/clo ratio, is approximately the same for both uniforms (0.10 for the CVC + MOPP IV and 0.13 for the Cold Wet Uniform); thereby allowing similar heat transfer in a hot environment when crewmen are sweating. The crew went from MOPP III to MOPP IV after 30 minutes and remained in MOPP IV for approximately two hours.

Environment and Climate Control Systems. The chamber conditions for the test were approximately a WBGT index of 83°F (T_{db} = 91°F, rh = 60%) with minimal wind speed. As outlined in TB Med 507 (5) the WBGT index is the most practical index for determining the physiological impact of the environment on the individual. This index is determined by adding 70% of the wet bulb temperature, 20% of the black globe temperature and 10% of the dry bulb temperature. According to the guidelines in this TB Med, a 10°F adjustment in the WBGT index is made to account for the effects of the NBC protective uniform. Therefore an individual dressed in the MOPP IV configuration in the chamber will experience an environmental stress equivalent to a WBGT index of 93°F. This exceeds the maximum limit of safety for physical training and strenuous exercise. The M1E1 Tank was equilibrated with the environmental conditions 12-24 hours prior to testing.

The turbine powered engine of the M1E1 Tank in combination with the Garrett System (air distribution) is capable of supplying 200 cfm of air between 50-75°F to the crew compartment. In the present test an independent cooling unit was used to simulate the air distribution of the M1E1 since the turbine cannot be operated in the chamber. Two approaches for the use of this supply were tested. The first approach supplied an air "shower" of 47 cfm to each of the crewman's areas (assuming equal distribution of the total incoming 200 cfm). In addition, approximately 3 cfm of cooled air was supplied to the M25 Gas Mask. The second approach combined compartment cooling with individual vest cooling. Vest cooling supplied approximately 15 cfm of air distributed to the chest (5-6.5 cfm), neck (2-3 cfm) and back (6.5-7 cfm). This was in addition to the 3 cfm supplied to the mask. The balance of the 200 cfm was dumped into the compartment (~ 130 cfm). The cooling vest was worn under the Kevlar vest, which was worn under the CVC clothing.

TABLE 2

Test Schedule

		Operation	Chamber Conditions T_{db} (°F)/rh (%)	Crew	Clothing	Climate Control System
Day 1	am	Tank Instrumentation	65-75/ < 50	---	----	Set-up/Test
		Crew Briefing	----	A+B	----	----
	pm	Dry Test Run	65/ < 50	A+B	CVC+MOPP III and IV	None or Test
Day 2	am					
		Chamber Heating	91/60	---	----	Test
	pm					
Day 3	am	Test	91/60	A	CVC+MOPP III and IV	Vest, Bulk + Mask Cooling
	pm	Test	91/60	B	CVC+MOPP III and IV	Air Shower + Mask Cooling
Day 4	am	Test	91/60	A	CVC+MOPP III and IV	Air Shower + Mask Cooling
	pm	Test	91/60	B	CVC+MOPP III and IV	Vest, Bulk + Mask Cooling
Day 5	am	Test	91/60	A	CVC+MOPP III and IV	Mask Ambient
	pm	Test	91/60	B	CVC+MOPP III and IV	Mask Ambient
Day 6	am	Make-up				

In addition to these two microclimate approaches, the back-up NBC protective system was also tested (i.e., the M13A1 particulate filter system, which supplies filtered ambient air to the M25 Mask). This system does not circulate the air in the turret.

With all tests the tank commander's hatch was "popped" and all others were closed using plexiglass hatches. During a 15-minute rearming period midway through the first and second hours of testing the loader's hatch was opened.

Test Schedule and Procedures. The schedule of this test is outlined in Table 2. After two days of preliminary work, there were three days of testing in the heat. The tank crews were tested in CVC plus MOPP III and IV, once with vest and compartment cooling, once with air shower, and once with the M13A1 gas particulate system (one crew only). Each crew performed one, 2-hour and 45-minute test per day. The two crews alternated cooling systems on the first two test days.

Crew Activity. The crew entered the tank in MOPP III, performed routine checks of the systems and attached masks and vests to the cooling systems when appropriate for a given test. Following this 30-minute period, an alarm was given whereby crews masked with hoods attached (i.e., MOPP IV). Fifteen minutes were taken to complete these procedures before the start of the simulated tank exercise.

Table 3 shows the activity of the crew during the two-hour period following the alarm. The loader who was required to move two types of inert rounds (kinetic energy, 43.5 pounds; high explosive antitank, 51.7 pounds) engaged in the most strenuous activity. These movements were performed during loading and unloading of the breech, restorage of the rounds in the ready rack, and rearmament of the tank. Maximal lifting height and carrying distance were two feet and four feet, respectively. Metabolic heat production of the driver, gunner and loader were obtained during Day 2 of the testing by collection of expired air.

Volumes of air were measured by use of Max Planck gasometers and concentrations of oxygen and carbon dioxide were determined from aliquot samples. The metabolic heat production of the driver in crew B was 146 W, whereas the two gunners averaged 200 W. These values represent rest and light exercise, respectively. In contrast, the loaders' values were quite high. The average heat production approached 360 W, which represented heavy exercise, especially considering that the loader's task involved predominantly upper body exercise. Heart rate values were approximately 100 beats per minute for the gunner and commander, whereas the driver's values were substantially lower. In contrast, the loader exceeded 185 beats per minute during exercise periods.

TABLE 3

Crew Activities

	Event	Number	Duration (min)	Rounds Expended
Phase 1	Engagement	9	30	300 7.62 mm, 50 cal 19 KE 3 HEAT
	Rearmament	1	15	
Phase 2	Engagement	6	15	100 50 cal 17 KE
Phase 3	Engagement	9	30	300 7.62 mm, 50 cal 19 KE 3 HEAT
	Rearmament	1	15	
Phase 4	Engagement	6	15	100 50 cal 17 KE
TOTAL	Engagement	30	90	800 7.62, 50 cal 72 KE 6 HEAT
	Rearmament	2	30	

KE is kinetic energy round; HEAT is high explosive antitank round.

Physiological Measurements and Safety Procedures. Since the WBGT index of 93°F in the chamber approached the safety limits established in TB MED 507 (5) for activity in the heat (i.e., a WBGT index of 83°F plus the 10°F adjustment for chemical protection), crews were monitored continuously. Body core (rectal) and skin temperatures of each crewman were recorded and plotted continuously. A given crewman was removed from the test if core temperature reached 39.5°C (103°F) or the exposure became intolerable. Skin temperatures were monitored by the placement of three thermocouples, one each, on the calf, chest and forearm; a thermistor was inserted four inches into the rectum for a measurement of core temperature; and heart rate was telemetered and recorded from three surface electrodes placed on the chest. All equipment utilized in this test is presented in the packing list shown in Appendix A. In addition to crew monitoring, medical support had been obtained from the Kirk Army Health Clinic (AHC), APG, MD. Two medical aidemen with an ambulance were "on call". A water source was available in the test area.

RESULTS

Environmental Conditions

Figure 1 illustrates the environmental conditions in the tank and chamber. These values are averages of the air shower tests since there are no differences between any of the tests. It is evident from this figure that the chamber dry bulb temperature averaged 33°C (91°F) whereas the T_{wb} averaged approximately 26.5°C (78°F) throughout the test period. The WBGT index reached an average of 28.5°C (83°F). The temperatures within the crew compartment were substantially reduced during both air shower and vest tests. The T_{db}, T_{wb} and WBGT index values were approximately 28°C (82.4°F), 19.5°C (67.1°F) and 22°C (71.6°F), respectively. There were no differences ($p > 0.05$) in tank conditions between air shower and vest tests.

Physiological Responses

Table 4 presents the final physiological responses of the crews during vest and air shower microclimate tests. The values of the two crews were combined since there were no differences between crews. Rectal, skin and mean body temperatures were statistically higher during air shower compared to vest tests. Heart rate and sweat loss values during the air shower test were statistically elevated above those values obtained during the vest test. The physiological responses of the crewmen in each position during the vest and air shower tests are shown in Table 5. In general, the loaders' responses were higher than the other crewmen whereas the drivers had the lowest responses.

TABLE 4

Final Physiological Responses of the Crews during Vest and Air Shower Microclimate Tests

		Vest	Air Shower	Diff
Rectal Temperature	(°C)	37.2 (0.2)	37.6 (0.5)	0.4*
	(°F)	99.0	99.7	
Mean Skin Temperature	(°C)	30.9 (5.1)	35.7 (1.0)	4.8**
	(°F)	87.6	96.3	
Mean Body Temperature	(°C)	35.1 (0.7)	37.0 (0.5)	1.9**
	(°F)	95.2	98.6	
Heart Rate	($b \cdot min^{-1}$)	91 (16)	112 (28)	21*
Sweat Loss	(liters)	0.64 (.17)	1.29 (.61)	.65**

Values are means (standard deviation); *is $p < 0.05$; **is $p < 0.01$.

TABLE 5

Final Physiological Responses of the Crews by Position during Vest and Air Shower Microclimate Tests

	Driver	Gunner	Loader	Commander
Rectal Temperature (^{o}C)				
Cooling Vest	36.74	37.27	37.45	37.28
difference	0.04 ↓	0.25 ↓	0.91 ↓	0.61 ↓
Air Shower	36.70	37.52	38.36	37.89
Mean Skin Temperature (^{o}C)				
Cooling Vest	31.00	32.01	30.48	30.07
difference	4.34 ↓	3.23 ↓	6.55 ↓	5.12 ↓
Air Shower	35.34	35.24	37.03	35.19
Mean Body Temperature (^{o}C)				
Cooling Vest	34.82	35.52	35.13	34.88
difference	1.43 ↓	1.24 ↓	2.78 ↓	2.11 ↓
Air Shower	36.25	36.76	37.91	36.99
Heart Rate ($b \cdot min^{-1}$)				
Cooling Vest	77	92	111	83
difference	4 ↓	10 ↓	33 ↓	39 ↓
Air Shower	81	102	144	122
Sweat Loss (kg)				
Cooling Vest	0.26	0.58	1.11	0.62
difference	0.33 ↓	0.57 ↓	1.09 ↓	0.60 ↓
Air Shower	0.59	1.15	2.20	1.22

The average rectal and mean skin temperature responses of the crewmen by position over time for each of the three different tests are illustrated in Figures 2,3 and 4. As illustrated in Figure 2, a substantial gradient ($\bar{X}$, 6.3^{o}C; range, 5-7^{o}C) was established between the mean skin and rectal temperatures. This large gradient appeared to be sufficient to maintain rectal temperatures throughout this test at the pre-exposure values for the drivers, gunners and commanders. However, there was a slight increase in rectal temperature for the loaders.

During the air shower test, a much smaller gradient between mean skin and rectal temperatures was noted as illustrated in Figure 3. In fact, the loaders' responses showed that the differences were as small as 1.5°C. These smaller gradients may have contributed to the slight increases in rectal temperature for the gunners and commanders as shown in Figure 3. The loaders showed moderate increases throughout the exposure whereas the rectal temperatures for the drivers remained essentially unchanged.

During the M13A1 test, minimal skin to rectal temperature gradients were evident as illustrated in Figure 4. Rectal temperature increased moderately for the driver, gunner and commander, whereas the the loader's response was higher than the other crewmen. The tank commander blacked out at approximately 66 minutes into the test despite relatively low rectal and skin temperatures of 37.9°C (100.2°F) and 37.0°C (98.6°F), respectively. At 84 minutes, the gunner was removed because of dry heaving. His values were 38.0°C (100.4°F) rectal temperature, and 37.1°C (98.8°F) skin temperature. The loader appeared to be under the greatest thermal strain with average final rectal and skin temperatures of 38.4°C (101.1°F) and 38.1°C (100.6°F), respectively (c.f. Fig. 4). This test was terminated when two of the crewmen became incapacitated.

The average heart rate responses for the crewmen during the vest, air shower and M13A1 tests are illustrated in Figure 5. It is evident that the heart rate responses are lower during the vest test compared to both air shower and the M13A1 tests. The range in heart rate responses is illustrated by the drivers' and loaders' values (Figure 6). The drivers were essentially at rest in a semi-reclined position, whereas the loaders were predominantly standing and doing heavy intensity upper body exercise. The final heart rate values during air shower test were statistically higher ($p < 0.05$) than the vest test (Table 4).

Figure 7 compares the average total sweat loss responses of the drivers, gunners, loaders and commanders during the vest and air shower tests. It is quite evident that the total sweat loss values were nearly twice as high during the air shower test as compared to the vest test (c.f. Table 4). It is also obvious from Figure 7 that the loaders' sweat losses are nearly twice that of the other crewmen.

DISCUSSION

The climatic conditions for this test were established to approximate those conditions that should occur about 1% of the time during the summer in central Europe. That is, it can be expected that one day out of one hundred will have environmental conditions of 33°C (91°F) dry bulb and 26.5°C (78°F) wet bulb temperatures with relative humidity of 60%. The environmental conditions inside the vehicle were substantially improved by both the air shower and vest cooling tests and by an equal magnitude. The performance of the simulated turbine bleed air appeared to be quite good at these ambient conditions.

The physiological responses of the two crews were similar and therefore all comparisons between tests reflect the combined responses of the two crews. The temperature responses of the crews were quite different between air shower and vest auxiliary cooling tests. During the vest tests, the skin temperatures were low. In the case of one driver, the cooling was very uncomfortable and this required the adjustment of the air flow to avoid extreme discomfort. A nearly 10°F average skin temperature difference was established between the vest and the air shower test. This substantial difference would suggest that the crews' thermal comfort was greater during vest auxiliary cooling.

Despite the fact that the environmental conditions were substantially improved with the air shower, the combination of insulation and low permeability

of the CVC and chemical protective clothing prevented sufficient heat dissipation to maintain normal core temperatures. Rectal temperature responses were significantly different ($p < 0.05$) between air shower and vest tests. The responses were lower during the vest test due to the larger thermal gradients established by the lower skin temperatures. The average rectal temperatures were relatively low during both vest (99.0^{o}F) and air shower (99.7^{o}F) tests. These values indicate that, on the average, the crews experienced moderate heat strain in both conditions during this test. However, individual responses appear to be a better indicator of crew distress. The responses of the loaders exemplify the upper range of thermal strain during this test. In these cases, rectal temperature averaged approximately 100.2^{o}F. This is not surprising. According to the Heat Causalty Assessment Model (2) within this type of environment and clothing configuration, the rectal temperature response is very sensitive to the metabolic heat production. In this test, the loaders performed heavy lifting tasks which had very high metabolic heat productions and correspondingly high rectal temperatures relative to the other crew members.

Heart rate and sweat loss responses complimented these thermal responses. During the air shower tests the final heart rates and total sweat losses were higher ($p < 0.05$) than during the vest tests. It is postulated that the higher heart rate response during the air shower tests was a function of an increased dilation of the skin vascular bed and the decreasing central blood volume with the increasing sweat loss.

A factor contributing to these higher heart rates during air shower was the state of heat acclimation of the crewmen. None of the crewmen were previously acclimated to the heat although some of the crewmen engaged in regular physical activity which might have partially acclimated them. Acclimation to the heat reduces heart rate and rectal temperature responses while improving

sweat production during exposures to the heat. However, it is questionable whether acclimation would improve the thermal responses of crewmen dressed in chemical protective clothing which is known to retard both dry and evaporative heat exchange.

Sweat loss responses were quite different between air shower and vest tests. In fact, the sweat loss during air shower was nearly twice as great as the value elicited during the vest test. This substantiates earlier findings which have demonstrated the benefits of water conservation provided by vest cooling (6,7). In the present study during the nearly three-hour total exposure time, differences of nearly 2.7 liters (2.8 quarts) of water for the crew were conserved with vest cooling compared to air shower cooling.

CONCLUSIONS

It is quite clear from the results of this study that vest auxiliary cooling provides a more effective use of the turbine bleed air than is provided by an air shower. The vest approach seems to improve the thermal comfort of these tank crew members in an environment which normally would be thermally stressful. This improved thermal comfort from vest cooling is probably associated with the reduced mean skin temperature seen under these conditions which has been found previously to be significantly correlated with estimates of thermal discomfort. Vest cooling also conserves water as determined by sweat loss measurements above that which is conserved by the air shower. In the present study during the nearly 3-hour exposure time, differences of nearly 2.7 liters (2.8 quarts) or water for the crew were conserved with vest cooling compared to air shower cooling. It can be seen from Table 4 that all final physiological responses of the crews during vest and air shower microclimate tests were statistically in favor of the vest. However, it must also be emphasized that for these ambient conditions and time period only, the air shower provided an adequate minimum cooling power. Despite the fact that the crewmen were extremely uncomfortable, all physiological data indicated that these crews were only moderately heat strained within this 3-hour exercise period.

ACKNOWLEDGEMENTS

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Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 70-25 on Use of volunteers in Research.

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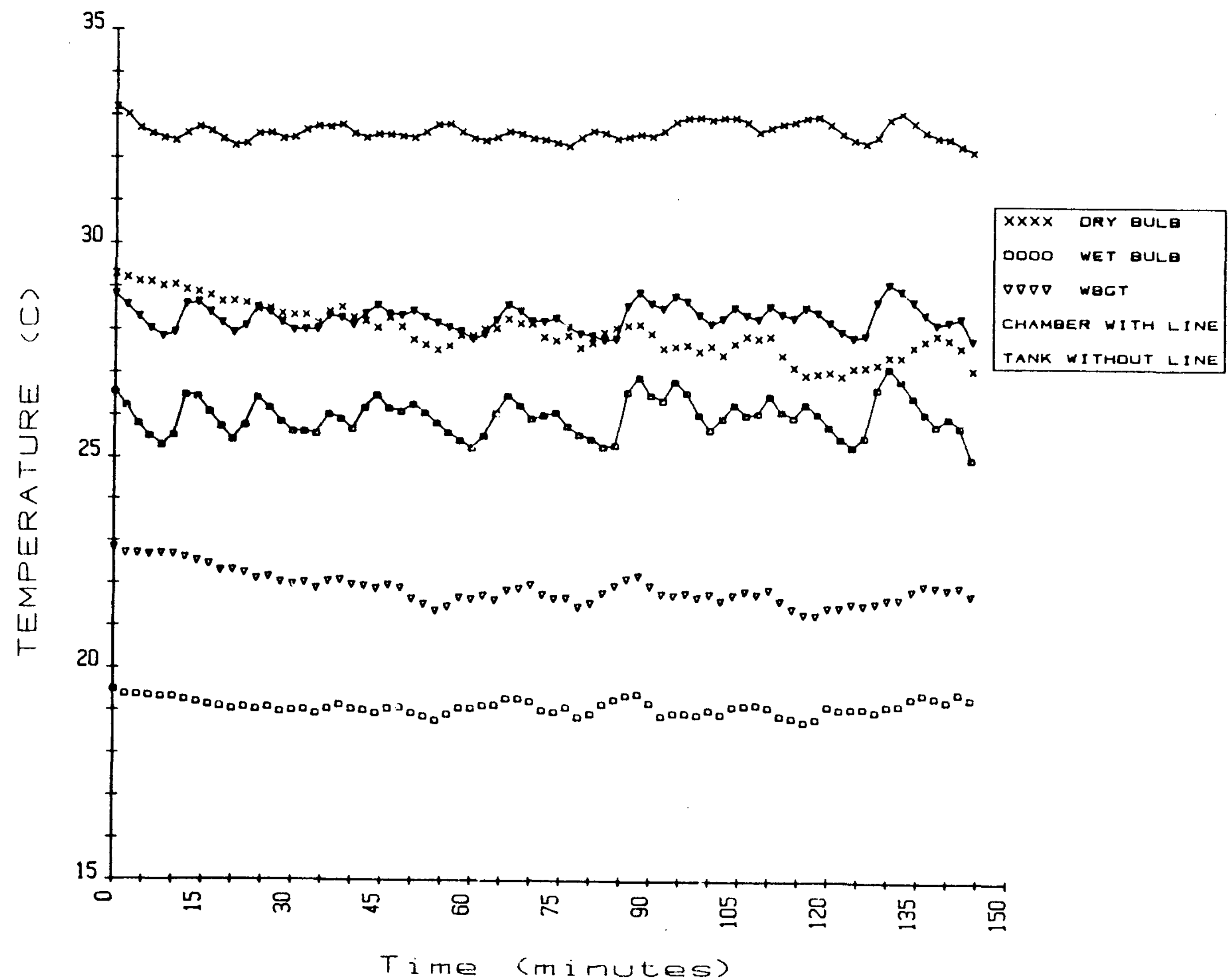


Figure 1. Environmental Conditions in the Chamber and Tank during the Air Shower Test.

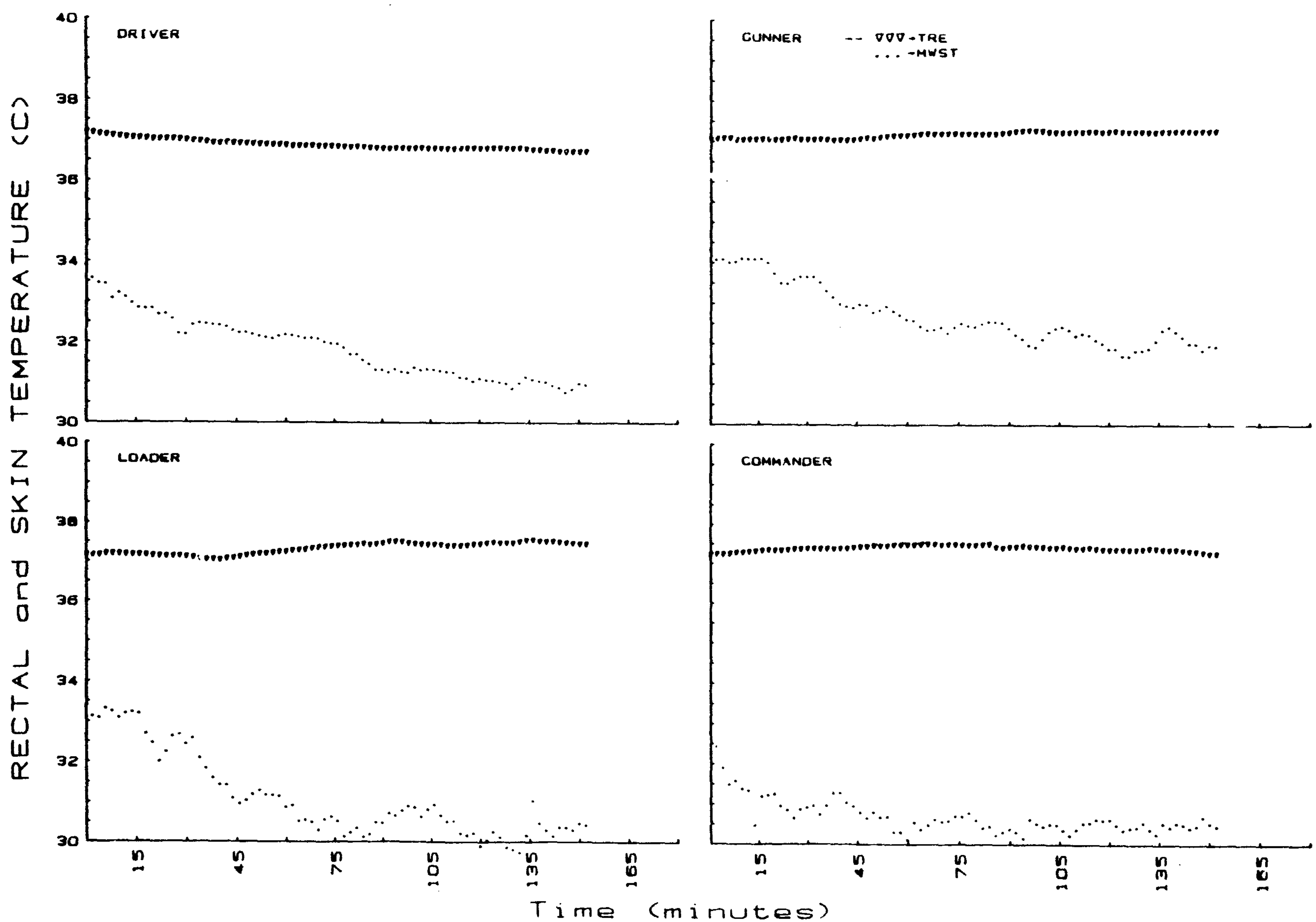


Figure 2. Average Skin and Rectal Temperatures of the Drivers, Loaders, Gunners and Commanders during Vest Tests.

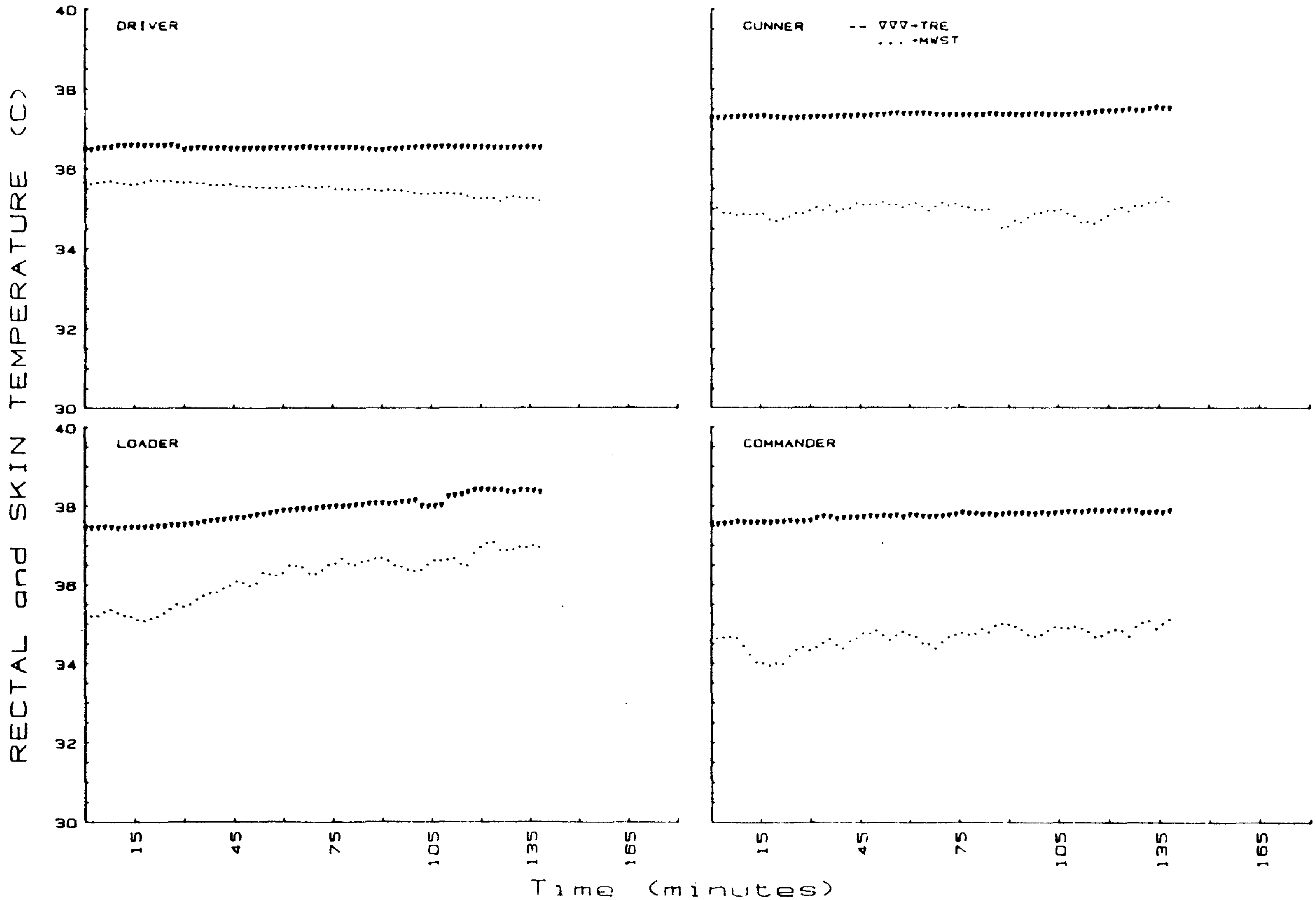


Figure 3. Average Skin and Rectal Temperatures of the Drivers, Loaders, Gunners and Commanders during Air Shower Tests.

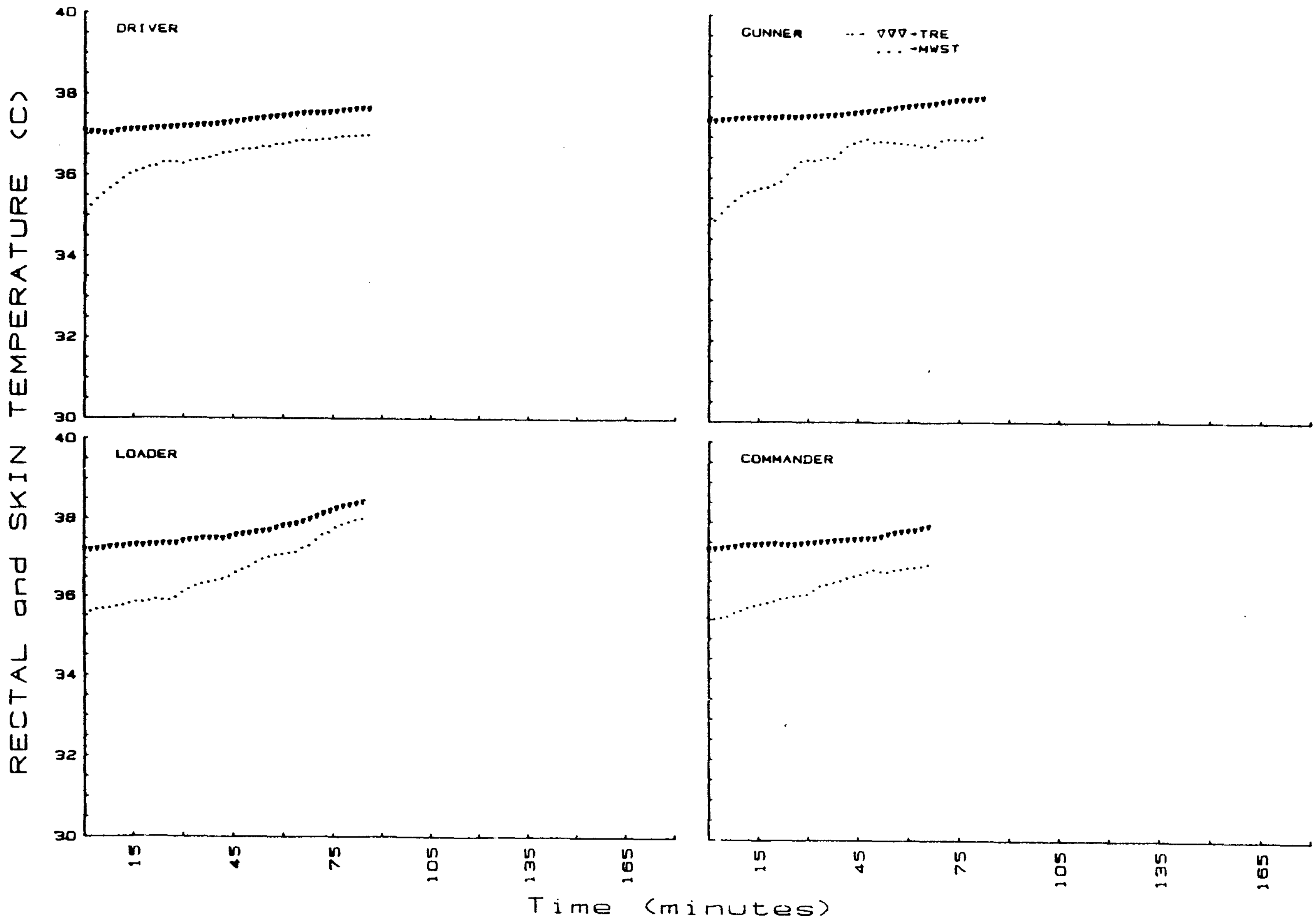


Figure 4. Average Skin and Rectal Temperatures of the Driver, Loader, Gunner and Commander during M13A1 Test.

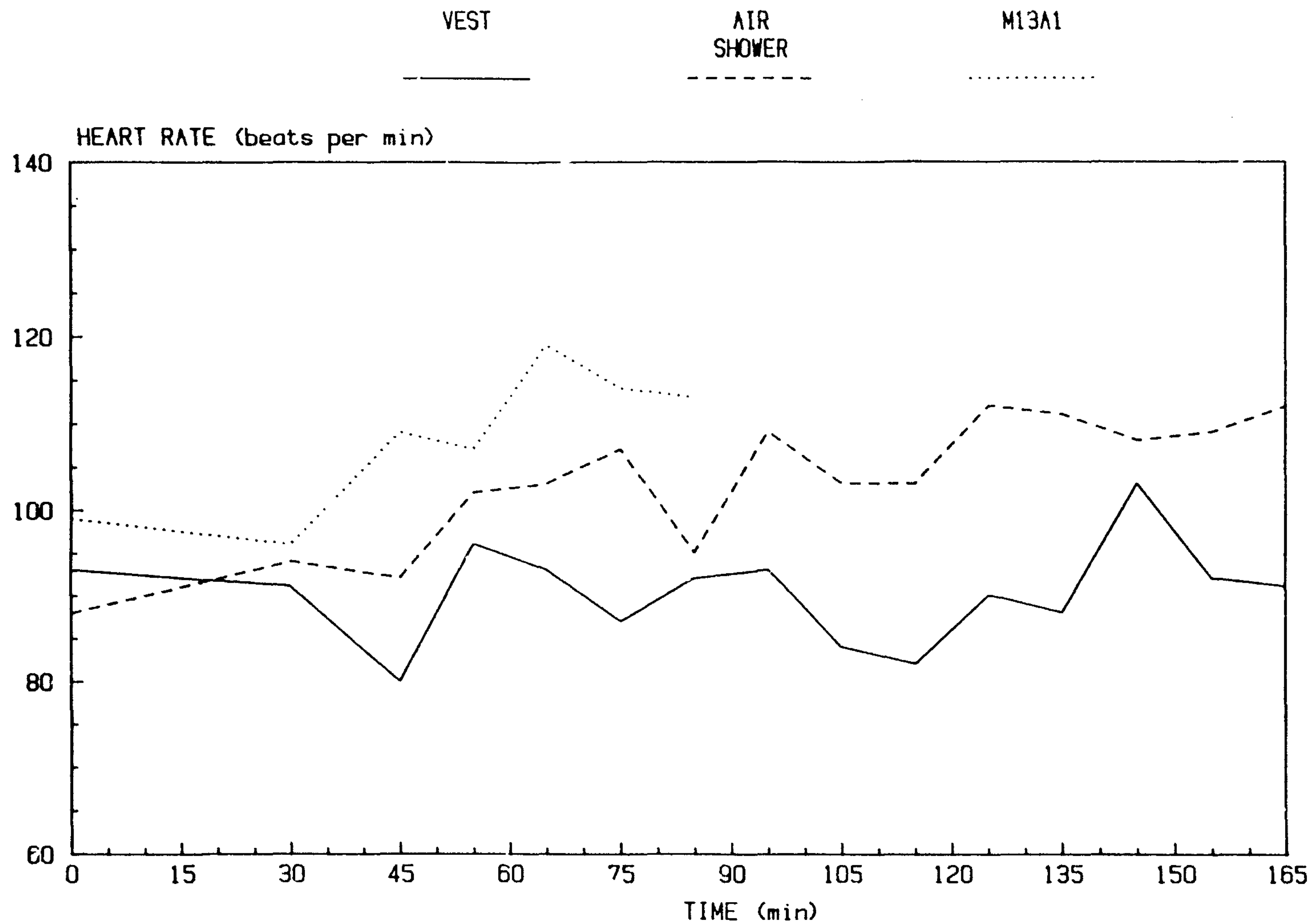
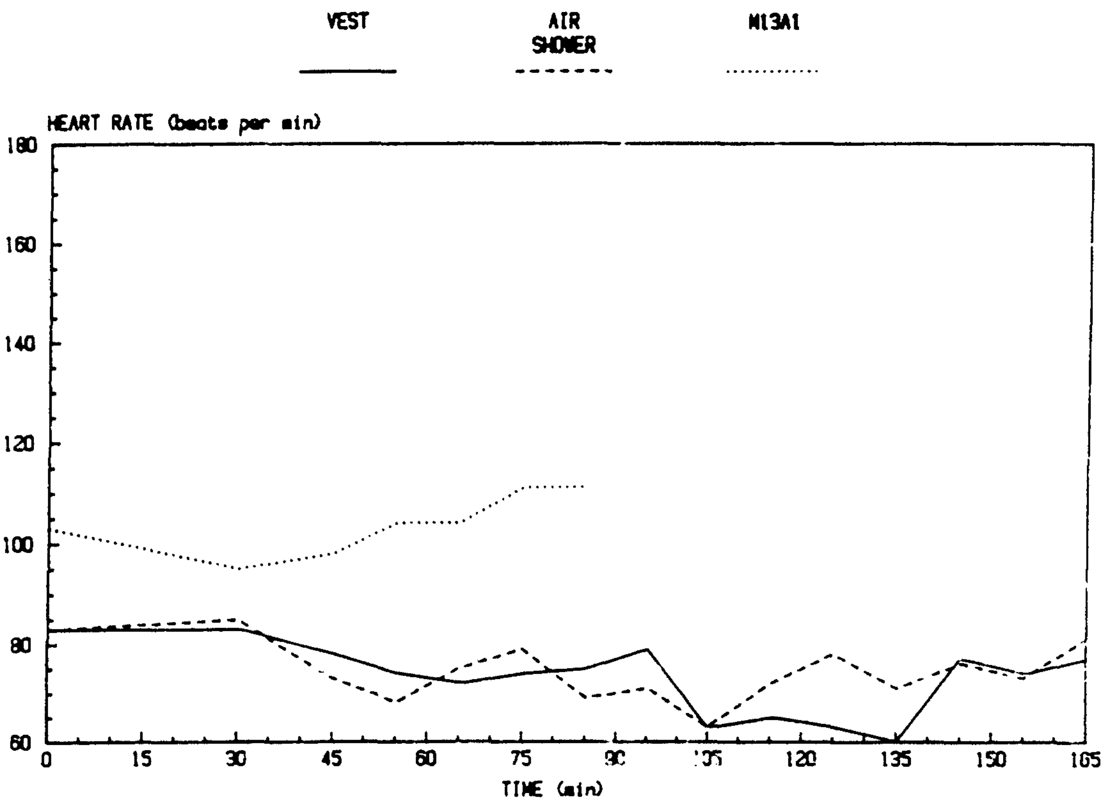


Figure 5. Average Heart Rate Responses for the Crewmen (n = 8) during the Vest, Air Shower and the M13A1 (n = 4) Tests.



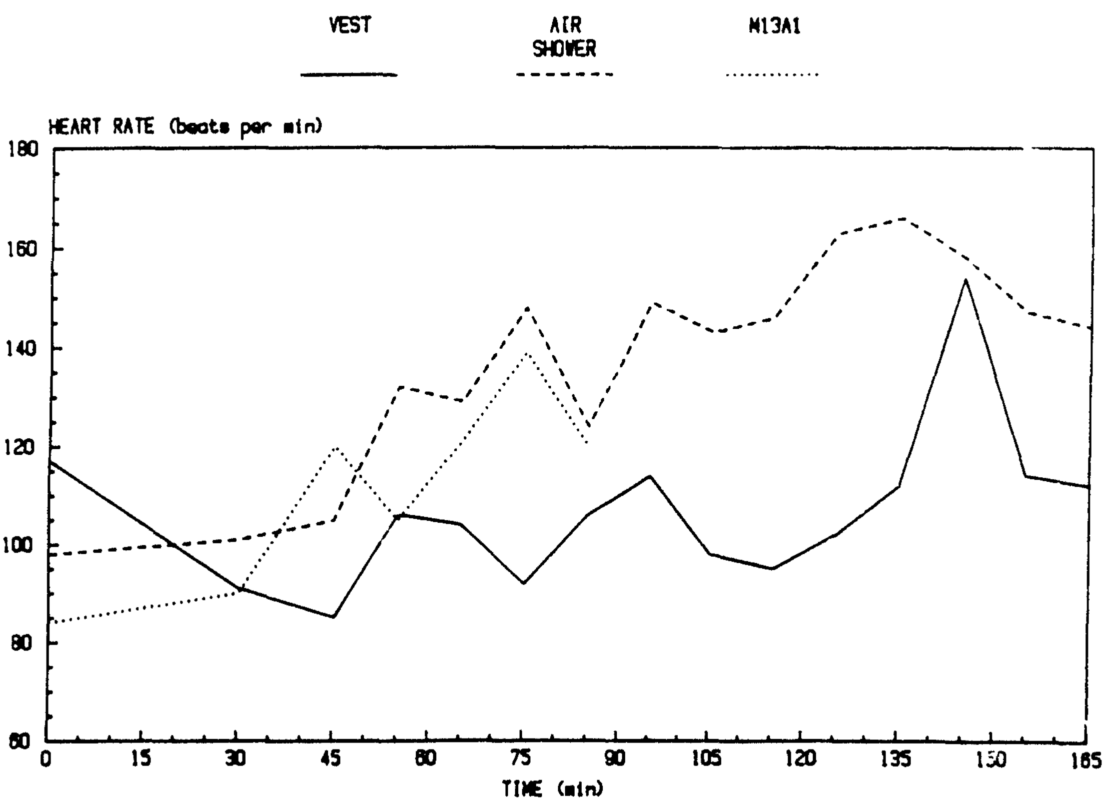


Figure 6. Average Heart Rate Responses for the Drivers (above) and Loaders (below) during Vest, Air Shower and M13A1 (n = 1) Tests.

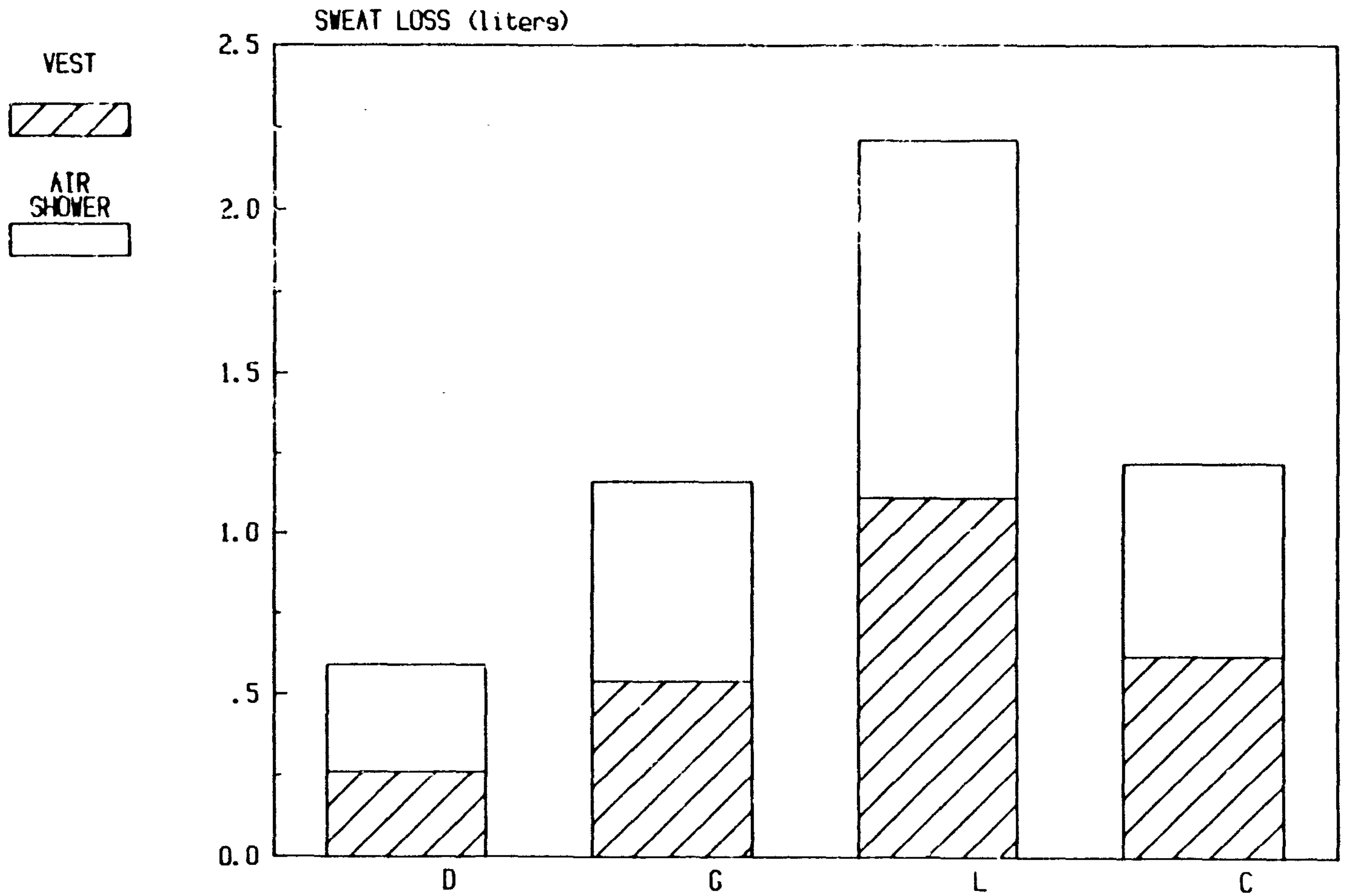


Figure 7. Average Total Sweat Loss of the Drivers (D), Gunners (G), Loaders (L) and Commanders (C) during the Vest and Air Shower Tests.

APPENDIX A

ABERDEEN PACKING LIST

Box #1 | 25x25x16 inches | 44.51 Kg (97.9 lbs.)

Quantity	Item
1	Hewlett Packard (H.P.) digital multi meter
1	H. P. 60 channel scanner

Box #2 | 29x25x16 | 44.25 Kg (97.4 lbs.)

Quantity	Item
1	H.P. 60 channel scanner (backup)
1	H.P. IB interface cable (2 meters)
1	H.P. real time clock interface
1	Pkg. 4x4 gauze

Box #3 | 28x24x13 | 40.53 Kg (89.2 lbs.)

Quantity	Item
1	H.P. 9872 plotter
1	Box plotter paper
1	H.P. IB cable
1	WBGT kit without harness
2	WBGT kit with harness
8	loop couple skin harnesses
2	straight couple skin harnesses
10	rectal probes
2	13 ft. conductor cables

Box #4 | 23x21x16 | 33.13 Kg (72.9 lbs.)

Quantity	Item
1	H.P. 9866 printer
1	H.P. 9866 cable #6
2	Botsballs without harness
2	Botsballs with harness
1	ECG simulator
1	sound meter
1	parachute cord 100 ft.
	assorted colored tape
	spare thermocouples, straight and looped
2	sponges
1	plastic bottle (for rectal sterilization)

Box #5 28x24x14 43.70 Kg (96.1 lbs.)

Quantity	Item
1	Alnor hot wire anemometer with sensor
1	Chino wet bulb/dry bulb sensor with stand
2	Yellow Springs rectal boxes
1	wind speed transmitter with cups
1	H.P. 5300 B counter (for wind speed)
2	boxes assorted Hi-tape (for skin couples)
10	rolls ECG paper
6	rolls H.P. printer paper for 9825
3	box alcohol pads
1	H.P. timing generator
5	ECG cables
5	ECG harnesses
1	yellow multi box

Box #6 29x24x9 39.95 Kg (87.9 lbs.)

Quantity	Item
1	heart rate monitor
-	H.P. scanner cables
1	Chino wet bulb/dry bulb sensor with wicks
5	H.P. certified data cartridges
1	YSI rectal box
1	box (30) non-allergenic electrodes
2	tubes K-Y jelly
2	box magnets
10	disposable razors
3	pr. sunglasses
1	bottle rectal disenfectant
6	plastic beakers
7	skin harness extension cables
10	rectal harnesses with belts

Box #7 27x22x12 26.08 Kg (57.4 lbs.)

Quantity	Item
1	H.P. timing generator
1	H.P. clock
2	rolls H.P. printer paper
2	pkg. 4x4 gauze
5	canteens

200	ECG electrodes
	plastic bags
	clip boards
	10x13 envelopes

Box #8 Footlocker 39.29 Kg (86.4 lbs.)

Quantity	Item
1	digital electronic scale
2	base plates with clamps
1	rechargable soldering iron
	assorted plastic ties (flat and ribbon)
1	roll hook up wire
1	pkg. cotton applicators
2	pkg. H.P. plotter pens (4 colors)
1	BCD cable (binary convert digital)
2	D cell batteries
3	bottle insect repellent
2	250 ml. graduated cylinders
1	skin fold calipers
	assorted office supplies
	assorted supplies-elastics for harnesses, RTV sealant, skin lotion, 4x4 gauze, plastic bags, disposable wipes

Box #9 Footlocker 39.29 Kg (86.4 lbs.)

Quantity	Item
6	15 ft. yellow extension cables
2	60 ft. yellow extension cables
3	rectal junction boxes
2	Botsball extensions
1	wind speed power supply, extension cable, BCD cord
11	H.P. power cords
3	rechargable pulsimeters
1	WBGT (Weksler) without harness
4	H.P. cables
4	15' rectal extension cables
1	first aid kit
1	USARIEM emblem

Box #10	26x26x19		29.99 Kg (66.0 lbs.)
		Item	
		Green junction box for skin and rectal connections to scanners	
Box #11	Briefcase		
		assorted tools	
Box #12	Vinyl case		
		9825 calculator	
		program tapes #406 to 409	
		printer paper, power cords	
Box #13	Briefcase		
		3 walkie talkies with chargers	
		1 Nikon 35 mm camera	
		1 flash attachment (for camera)	
		film	
		1 power supply for flash	

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